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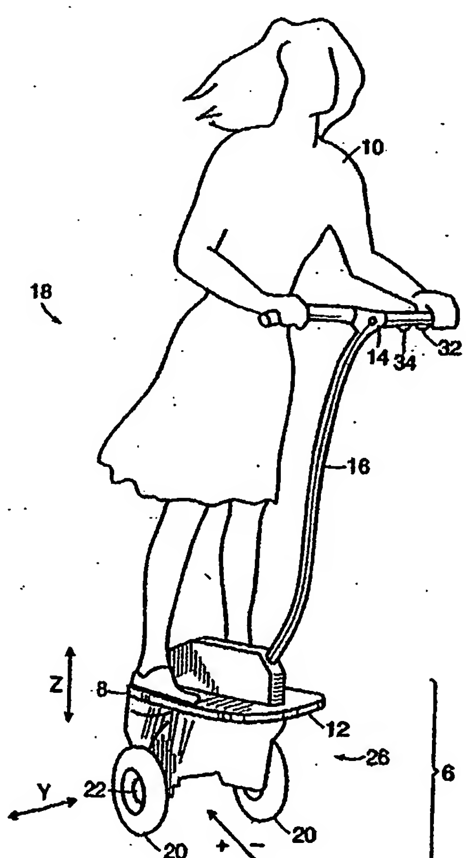
(54) Title: PERSONAL MOBILITY VEHICLES AND METHODS



(57) Abstract: A class of transportation vehicles for carrying an individual (10) over ground having a surface that may be irregular. Various embodiments have a motorized drive, mounted to the ground-contacting module (6) that causes operation of the vehicle in an operating position that is unstable with respect to tipping when the motorized drive arrangement is not powered. Related methods are provided.

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PERSONAL MOBILITY VEHICLES AND METHODS

Technical Field

The present invention pertains to vehicles and methods for transporting individuals, and more particularly to balancing vehicles and methods for transporting individuals over ground having a surface that may be irregular.

Background Art

A wide range of vehicles and methods are known for transporting human subjects. Typically, such vehicles rely upon static stability, being designed so as to be stable under all foreseen conditions of placement of their ground-contacting members. Thus, for example, the gravity vector acting on the center of gravity of an automobile passes between the points of ground contact of the automobile's wheels, the suspension keeping all wheels on the ground at all times, and the automobile is thus stable. Another example of a statically stable vehicle is the stair-climbing vehicle described in U.S. patent no. 4,790,548 (Decelles et al.).

Summary of the Invention

In one embodiment there is provided a vehicle for carrying a user. In this case, the user is a standing person. The vehicle of this embodiment includes:

a. a ground-contacting module which supports a payload including the standing person, the ground-contacting module contacting an underlying surface substantially at a single region of contact; and

b. a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system.

In a related embodiment, the ground-contacting module includes a uniball.

In another embodiment, there is provide a vehicle for carrying a payload including a user. The vehicle of this embodiment includes:

a. a ground-contacting module including two substantially coaxial wheels;

b. a platform supporting the user in a standing position substantially astride both wheels; and

the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system wherein the motorized drive arrangement has a present power output and a specified maximum power output and, in operation, has headroom determined by the difference between the maximum power output and the present power output of the drive arrangement;

d. a headroom monitor, coupled to the motorized drive arrangement, for generating a signal characterizing the headroom; and

e. an alarm, coupled to the headroom monitor, for receiving the signal characterizing the headroom and for warning when the headroom falls below a specified limit.

The alarm may include ripple modulation of the power output of the motorized drive arrangement, and alternatively, or in addition, may be audible.

In a still further embodiment there is provided a device for carrying a user, and the device includes:

a. a platform which supports a payload including the user,

b. a ground-contacting module, mounted to the platform, including at least one ground-contacting member and defining a fore-aft plane;

c. a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system in an operating position that is unstable with respect to tipping in at least a fore-aft plane when the motorized drive arrangement is not powered; and

d. a user input control that receives an indication from the user of a specified pitch of the device under conditions of motion at uniform velocity.

The user input control may include a thumb-wheel disposed upon a handle that is part of the device. A related embodiment provides a device for carrying a payload including a user, and the device includes:

a. a platform which supports the user in a standing position,

vehicle to carry a user and this method includes:

a. standing on a ground-contacting module which supports a payload including a person standing thereon, the ground-contacting module contacting an underlying surface substantially at a single region of contact; and

b. operating a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system.

In a related embodiment, the ground-contacting module may include a uniball.

In another embodiment, there is provided a method of using a vehicle to carry a user, and in this embodiment, the method includes:

a. standing on a platform that supports a payload including a standing person, the platform mounted to a ground-contacting module including two substantially coaxial wheels; and

b. operating a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system.

In another embodiment, there is provided a method of using a vehicle to carry a payload including a user, and the method of this embodiment includes:

a. standing on a platform supporting the user, the platform mounted to a ground-contacting module, which propels the user in desired motion over an underlying surface;

b. using a proximity sensor to determine the presence of the user on the device; and

c. inhibiting operation of the ground-contacting module unless the proximity sensor has determined the presence of the user on the device.

As in the corresponding device, discussed above, the proximity sensor may be a member, mechanically coupled to the safety switch, having an operating position and a non-operating position, wherein the member is in the non-operating position in the absence of

includes:

a. assuming a position on a platform which supports a payload including the user, the platform being coupled to a ground-contacting module, the module including at least one ground-contacting member and defining a fore-aft plane;

b. operating a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system in an operating position that is unstable with respect to tipping in at least a fore-aft plane when the motorized drive arrangement is not powered; and

c. providing via a user input control an indication from the user of a specified pitch of the device under conditions of motion at uniform velocity.

The user input control may include a thumb-wheel disposed upon a handle coupled to the platform.

Yet another embodiment provides a method for carrying a payload including a user, and the method of this embodiment includes:

a. assuming a position on a platform which supports a payload including the user, the platform being coupled to a ground-contacting module, the module including at least one ground-contacting member and defining a fore-aft plane;

b. operating a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system in an operating position that is unstable with respect to tipping in at least a fore-aft plane when the motorized drive arrangement is not powered; and

c. operating a user-operated mode control to select one of first and second modes;

d. providing via a user input control an indication of one of (i) a specified

of the embodiment of Fig. 1;

Fig. 5 is a block diagram showing generally the nature of sensors, power and control with the embodiment of Fig. 1;

Fig. 6 is a block diagram providing detail of a driver interface assembly;

Fig. 7 is a schematic of the wheel motor control during balancing and normal locomotion, in accordance with an embodiment of the present invention;

FIG. 8 shows a balancing vehicle with a single wheel central to the support platform of the vehicle and an articulated handle in accordance with an embodiment of the present invention;

FIG. 9 shows a balancing vehicle with a single wheel central to the support platform of the vehicle and a handle in accordance with an embodiment of the present invention;

FIG. 10 shows a balancing vehicle with two coaxial wheels central to the support platform of the vehicle and an articulated handle in accordance with an embodiment of the present invention;

FIG. 11 shows a balancing vehicle with a single wheel central to the support platform of the vehicle and no handle in accordance with an embodiment of the present invention;

FIG. 12 shows an alternate embodiment of a balancing vehicle with a single wheel central to the support platform of the vehicle and no handle in accordance with an embodiment of the present invention;

FIG. 13 shows a balancing vehicle with a single wheel transversely mounted central to the support platform of the vehicle and no handle in accordance with an embodiment of the present invention;

FIG. 14 shows a balancing vehicle with a single wheel transversely mounted central to the support platform of the vehicle and a handle in accordance with an embodiment of the present invention;

FIG.15 shows a balancing vehicle with a uniball mounted central to the support platform of the vehicle and a handle in accordance with an embodiment of the present invention; and

FIG. 16 shows an illustrative diagram of an idealized balancing vehicle with a

In various embodiments of the invention, fore-aft stability may be achieved by providing a control loop, in which one or more motors are included, for operation of a motorized drive in connection with the ground-contacting members. As described below, a pair of ground-contacting members may, for example, be a pair of wheels or a pair of wheel clusters. In the case of wheel clusters, each cluster may include a plurality of wheels. Each ground-contacting member, however, may instead be a plurality (typically a pair) of axially-adjacent, radially supported and rotatably mounted arcuate elements. In these embodiments, the ground-contacting members are driven by the motorized drive in the control loop in such a way as to maintain, when the vehicle is not in locomotion, the center of mass of the vehicle above the region of contact of the ground-contacting members with the ground, regardless of disturbances and forces operative on the vehicle.

A ground-contacting member typically has a "point" (actually, a region) of contact or tangency with the surface over which the vehicle is traveling or standing. Due to the compliance of the ground-contacting member, the "point" of contact is actually an area, where the region of contact may also be referred to as a contact patch. The weight of the vehicle is distributed over the contact region, giving rise to a distribution of pressures over the region, with the center of pressure displaced forward during forward motion. The distribution of pressures is a function both of the composition and structure of the wheel, the rotational velocity of the wheel, the torque applied to the wheel, and thus of the frictional forces acting on the wheel.

A force in the direction of motion is required to overcome rolling friction (and other frictional forces, including air resistance). Gravity may be used, in accordance with preferred embodiments of the invention, to provide a torque about the point of contact with the surface in a direction having a component in the sense of desired motion. Referring to Fig. 16, to illustrate these principles, a diagram is shown of the forces acting on a vehicle that locomotes with constant velocity v on a single wheel over a flat surface. The principles now discussed may readily be generalized to operation on a sloped surface and to accommodate any other external forces that might be present. Wheel **160** of radius $\mathbf{R_w}$ rotates with respect to chassis **162** about axle **164** and contacts the underlying surface at point P. For purposes of illustration only, it is assumed that wheel **160** contacts the surface at a point.

of friction will result in acceleration since an additional forward-directed force acts on the CG. Conversely, in order to achieve acceleration (or deceleration) of the vehicle, additional leaning (forward or backward) must be provided in a manner discussed in further detail below.

Fig. 1 shows a simplified embodiment of the invention. A personal transporter is shown and designated generally by numeral 18. A subject 10 stands on a support platform 12 and holds a grip 14 on a handle 16 attached to the platform 12, so that the vehicle 18 of this embodiment may be operated in a manner analogous to a scooter. A control loop may be provided so that leaning of the subject results in the application of torque to wheel 20 about axle 22 thereby causing an acceleration of the vehicle. Vehicle 18, however, is statically unstable, and, absent operation of the control loop to maintain dynamic stability, subject 10 will no longer be supported in a standing position and will fall from platform 12. Different numbers of wheels or other ground-contacting members may advantageously be used in various embodiments of the invention as particularly suited to varying applications. Thus, as described in greater detail below, the number of ground-contacting members may be any number equal to, or greater than, one. For many applications, the dimensions of platform 12, and indeed of the entire ground-contacting module, designated generally by numeral 6, are advantageously comparable to the dimensions of the footprint or shoulder width of user 10. Thus transporter 18 may advantageously be used as a mobile work platform or a recreational vehicle such as a golf cart, or as a delivery vehicle.

Transporter 18 may be operated in a station-keeping mode, wherein balance is maintained substantially at a specified position. Additionally, transporter 18, which may be referred to herein, without limitation, as a "vehicle," may also maintain a fixed position and orientation when the user 10 is not on platform 12. This mode of operation, referred to as a "kickstand" mode, prevents runaway of the vehicle and provides for the safety of the user and other persons. A forceplate 8 or other sensor, disposed on platform 12, detects the presence of a user on the vehicle.

Another embodiment of a balancing vehicle in accordance with the present invention is shown in Fig. 2 and designated generally by numeral 24. Personal vehicle 24 shares the characteristics of vehicle 18 of Fig. 1, namely a support platform 12 for

loop is applied. **T** identifies the wheel torque. The remaining portion of the figure is the control used to achieve balance. The boxes **62** and **63** indicate differentiation. To achieve dynamic control to insure stability of the system, and to keep the system in the neighborhood of a reference point on the surface, the wheel torque **T** in this embodiment is governed by the following simplified control equation:

$$T = K_1(\theta+\theta_0) + K_2\dot{\theta} + K_3(x+x_0) + K_4\dot{x} \quad , \qquad \text{(Eqn. 4)}$$

where:

- T denotes a torque applied to a ground-contacting element about its axis of rotation;
- θ is a quantity corresponding to the lean of the entire system about the ground contact, with θ_0 representing the magnitude of a system pitch offset, all as discussed in detail below;
- x identifies the fore-aft displacement along the surface relative to a fiducial reference point, with x_0 representing the magnitude of a specified fiducial reference offset ;
- a dot over a character denotes a variable differentiated with respect to time; and
- a subscripted variable denotes a specified offset that may be input into the system as described below; and
- K_1, K_2, K_3, and K_4 are gain coefficients that may be configured, either in design of the system or in real-time, on the basis of a current operating mode and operating conditions as well as preferences of a user. The gain coefficients may be of a positive, negative, or zero magnitude, affecting thereby the mode of operation of the vehicle, as discussed below. The gains K_1, K_2, K_3, and K_4 are dependent upon the physical parameters of the system and other effects such as gravity. The simplified control algorithm of Fig. 3 maintains balance and also proximity to the reference point on the surface in the presence of disturbances such as changes to the system's center of mass with respect to the reference point on the surface due to body motion of the subject or contact with other persons or objects.

The effect of θ_0 in the above control equation (Eqn. 4) is to produce a specified offset $-\theta_0$ from the non-pitched position where $\theta=0$. Adjustment of θ_0 will adjust the vehicle's offset from a non-pitched position. As discussed in further detail below, in various embodiments, pitch offset may be adjusted by the user, for example, by means of

for simplicity in Fig. 3, separate motors may be provided for left and right wheels of the vehicle and the torque desired from the left motor and the torque desired from the right motor can be calculated separately in the general manner described below in connection with Fig. 7. Additionally, tracking both the left wheel motion and the right wheel motion permits adjustments to be made to prevent unwanted turning of the vehicle and to account for performance variations between the two drive motors.

In cases where gain K_3 is zero, a user control input such as a joystick may be used to adjust the torques of each motor. The joystick has axes indicated in Fig. 4. In operation of this embodiment, forward motion of the joystick is used to cause forward motion of the vehicle, and reverse motion of the joystick causes backward motion of the vehicle. A left turn similarly is accomplished by leftward motion of the joystick. For a right turn, the joystick is moved to the right. The configuration used here permits the vehicle to turn in place when the joystick is moved to the left or to the right, by causing rotation of left and right motors, and hence left and right wheels, at equal rates in opposite senses of rotation. With respect to forward and reverse motion an alternative to the joystick is simply leaning forward or backward (in a case where K_3 is zero), since the pitch sensor (measuring θ) would identify a pitch change that the system would respond to, leading to forward or reverse motion, depending on the direction of lean. Alternatively, control strategies based on fuzzy logic can be implemented.

It can be seen that the approach of adjusting motor torques when in the balance mode permits fore-aft stability to be achieved without the necessity of additional stabilizing wheels or struts (although such aids to stability may also be provided). In other words, stability is achieved dynamically, by motion of the components of the vehicle (in this case constituting the entire vehicle) relative to the ground.

In the block diagram of Fig. 5 it can be seen that a control system **51** is used to control the motor drives and actuators of the embodiment of Figs. 1-3 to achieve locomotion and balance. These include motor drives **531** and **532** for left and right wheels respectively. If clusters are present as in the embodiment of Fig. 2, actuators **541** and **542** for left and right clusters respectively. The control system has data inputs including user interface **561**, pitch sensor **562** for sensing fore-aft pitch, and wheel rotation sensors **563**, and pitch rate sensor **564**. Pitch rate and pitch may be derived

information signals as to pitch and pitch rate. (The term "inclinometer" as used in this context throughout this description and in the accompanying claims means any device providing an output indicative of pitch or pitch rate, regardless of the arrangement used to achieve the output; if only one of the pitch and pitch rate variables is provided as an output, the other variable can be obtained by suitable differentiation or integration with respect to time.) To permit controlled banking into turns by the vehicle (thereby to increase stability while turning) it is also feasible to utilize a second inclinometer to provide information as to roll and roll rate or, alternatively, the resultant of system weight and centrifugal force. Other inputs **294** may also be desirably provided as an input to the peripheral micro controller board **291**. Such other inputs may include signals gated by switches (knobs and buttons) for platform adjustment and for determining the mode of operation. The peripheral micro controller board **291** also has inputs for receiving signals from the battery stack **271** as to battery voltage, battery current, and battery temperature. The peripheral micro controller board **291** is in communication over bus **279** with a central micro controller board that may be used to control the wheel motors as described below in connection with Fig. 7.

Fig. 7 is a block diagram showing control algorithms, suitable for use in conjunction with the control assemblies of Fig. 6 to provide stability for a vehicle according to the embodiment of Figs. 1-2 and other embodiments in which the vehicle and payload are balanced on two ground-contacting members, both during locomotion and in a fixed position. The following conventions are used in connection with the description below:

1. Variables defined in world coordinates are named using a single subscript in capital letters. World coordinates are coordinates fixed to the earth (inertial).

2. A non-subscripted r identifies a wheel radius.

3. Lower case subscripts are used to indicate other attributes, e.g., right/left, etc.: r = right; l = left; ref = reference; f = finish; s = start.

4. All angles are positive in the clockwise direction, where positive travel is in the positive x direction.

5. A dot over a variable indicates differentiation in time, e.g., $\dot{\theta}$.

Fig. 7 shows the control arrangement for the motors of the right and left wheels.

3307 from compensated linear velocity input signals $r\dot{\theta}_{wl}$ and $r\dot{\theta}_{wr}$ for left and right wheels to obtain velocity error signals $\dot{x}_l$ and $\dot{x}_r$ for left and right wheels within the reference coordinate system. In turn the average of these signals, determined via summer 3317 and divider 3318, produces a linear velocity error signal $\dot{x}$. Displacement error signal x is derived by integrating $r\dot{\theta}_{wl}$ and $r\dot{\theta}_{wr}$ in integrators 3310 and 3309, limiting the results in saturation limiters 3312 and 3311, and then averaging their outputs via summer 3313 and divider 3315. The difference between these displacements, determined via summer 3314, produces the yaw error signal ψ.

The yaw error signal ψ is run through a standard proportional-plus-integral-plus-derivative (PID) control loop 3316, the output of which is combined with the output of the basic balancing torque command of summer 3319, to produce the individual wheel torque commands, which cause the wheels to maintain fore-aft stability and also cause the vehicle to align itself with the axes of, and follow the origin of, the reference coordinate system as directed by directional input 3300.

Let us now consider how this control causes the vehicle to start. The the directional input 3300 (which may be a joystick) which will provide a positive x for forward motion. The signal is divided and summed in summers 3308 and 3307, and subtracted from the right and left wheel velocity $\dot{x}_R$ and $\dot{x}_L$ providing a negative correction; this correction leads ultimately to a negative torque contribution at summer 3319, causing the wheels to move *backward*, so as to create a torque due to gravity that causes the vehicle to lean forward. This forward lean leads to changing θ and $\dot{\theta}$, which leads to positive corrections in summer 3319, causing the vehicle to move forward. Thus, moving the joystick forward or backward will cause the vehicle to lean forward or backward, as the case may be, and to move in the direction of the lean. This is a property of the control of Fig. 7. An equivalent result can be achieved by leaning, where K_3 is zero.

Anytime acceleration of the vehicle is desired, it is necessary to establish system lean. For example, to achieve forward acceleration of the vehicle, there must be forward system lean; the center of gravity of the system (vehicle and payload) must be placed forward of the center of the pressure distribution of the contact region where the wheels

returned to its original value.

One method for determining the speed limit of the vehicle is to monitor the battery voltage, which is then used to estimate the maximum velocity the vehicle is currently capable of maintaining. Another method is to measure the voltages of the battery and the motor and to monitor the difference between the two; the difference provides an estimate of the amount of velocity margin (or 'headroom') currently available to the vehicle.

Leaning of the user may additionally be limited, in accordance with a further embodiment of the invention, by a physical constraint such as a vertical member coupled to the platform, thus preventing leaning, in any specified direction, beyond the physical constraint.

The pitch offset, allowing modification of θ_0, as discussed above in reference to Equation 4, may be adjusted by the user by means of thumb-wheel 32 (shown in Fig. 1). Additionally, a secondary control 34 (shown in Fig. 1) may be provided, in accordance with embodiments of the invention, for changing the control architecture or function of the thumb-wheel. Thus, thumb-wheel 32 can also be put into a mode that operates to drive both wheels in the same direction. This allows a personal mobility vehicle such as vehicle 18 to be used as sort of a powered handcart that the user trails behind her or pushes ahead of her. This is especially useful when such a personal transporter has to be carried up stairs because the motors 531 and 534 (shown in Fig. 5) are used to lift the vehicle to the next riser so that the user does not have to use as much force as would otherwise be required. This mode of operation of the vehicle is referred to as "drive mode." Additionally, upon designation by the secondary selector 34, thumb wheel 32 may be used by the user for purposes of steering the vehicle.

The present invention may also be implemented in a number of further embodiments. We have found that a vehicle in accordance with the invention may act suitably as a prosthetic device for persons who have an impairment, caused by disease (such as Parkinson's Disease or ear disorders) or defect, in their ability to maintain balance or to achieve locomotion.

A control loop, as employed in accordance with an embodiment of the present invention, may advantageously be used for ameliorating the symptoms of balance-

Referring to Fig. 8, an alternate embodiment of the invention is shown in which ground contact is provided by a single wheel **44**. A characteristic common to many of the embodiments of the present invention is the platform **12** on which subject **10** stands to operate the vehicle. Handle **16** is provided in certain embodiments of the invention, as is grip **18** on handle **16** for subject **12** to grip. In one embodiment of the invention, shown in Fig. 8, handle **16** is rigidly attached to platform **12**, in this case, without limitation, via cowling **40**. In an alternate embodiment of the invention, shown in Fig. 9, handle **16** may be articulated at pivot **46** with respect to a base **48** fixed to platform **12**. Articulation of handle **16** at pivot **46** makes it easy for subject **10** to shift his weight forward or aft while maintaining one or both hands on grip **14**. Platform **12** locomotes with respect to the ground by motion of at least one wheel **20**, or other ground-contacting element. As with respect to earlier described embodiments, other ground-contacting elements such as arcuate members and clusters of wheels are described in the prior applications incorporated herein by reference, and the term "wheel" is used herein to refer to any such ground-contacting element without limitation.

The single wheel **44** of unicycle embodiments of Figs. 8 and 9 may be supplemented, as shown in Fig. 10, by a nearby wheel providing a pair of adjacent and coaxial wheels **20**. It can be seen that the vehicle of Fig. 10, like vehicles of various other embodiments disclosed in this description, when relying on wheels **20** for contacting the ground, is inherently unstable in the fore-aft direction with respect to a vertical **z**. While the vehicle of Fig. 10 is relatively stable in the lateral direction, vehicles of some other embodiments are unstable in both lateral and fore-aft directions. The motion of vehicle **18** may be controlled by subject **10** shifting his weight, and thus the center of mass (CG) of the loaded vehicle, in accordance with teachings described above.

Also, as described above, in addition to the direct effect, of subject leaning, on the variables governing the torque applied to a motor for directing the vehicle, or as an alternate control strategy, user input may be separately incorporated into the control loop in a manner equivalent to variation of one or more of the input variables. Thus, for example, the user may provide an input, by means of a user interface of any sort, the input being treated by the control system equivalently to a change, for example, in

the scope of the present invention, as described herein and as claimed in any appended claims, user **10** may be supported on platform **12** by standing with feet positioned along axis **56** of rotation of wheel **44**, as shown in Fig. 11, or, alternatively, with feet positioned astride axis **52** of rotation of wheel **44**, as shown in Fig. 12 and Fig. 13. A handle **16** may also be provided in the case of a configuration of the invention in which wheel **44** is mounted transversely to the direction faced by user **10**, with handle **16** coupled to platform **12** via cowling **40**, as shown in Fig. 14.

Fig. 15 shows an embodiment of a vehicle wherein the ground-contacting element is a uniball **151**. Such a ball may be separately driven in the x and y directions and the vehicle stabilized in one or both of these directions in the manner described above.

In addition to the personal mobility vehicles described and claimed above, in accordance with alternate embodiments of the invention, scaled down versions of any of the embodiments heretofore described may be employed for recreational or educational purposes, whether or not human subjects are conveyed thereupon. Such toy versions may travel over various terrains while maintaining balance in the fore-aft plane.

The described embodiments of the invention are intended to be merely exemplary and numerous variations and modifications will be apparent to those skilled in the art. All such variations and modifications are intended to be within the scope of the present invention as defined in the appended claims.

non-operating position, wherein the member is in the non-operating position in the absence of the user from the device and the member is moveable to the operating position when the user is on the device.

6. A device according to claim 5, wherein the member includes a plate, disposed on the device, for receiving a foot of the user, and wherein placement of the foot on the plate causes it to move into the operating position.

7. A device according to claim 4, wherein the proximity detector is electronic.

8. A device according to claim 4, wherein the proximity detector includes a semiconductor device.

9. A device according to claim 4, further comprising:

   d. a motorized drive arrangement, coupled to the ground-contacting module; the motorized drive arrangement causing, when powered, automatically balanced and stationary operation of the device unless the proximity sensor has determined the presence of the user on the device.

10. A vehicle for carrying a payload including a user, the vehicle comprising:

   a. a platform which supports the user;

   b. a ground-contacting module, to which the platform is mounted, which propels the user in desired motion over an underlying surface;

   c. a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system wherein the motorized drive arrangement has a present power output and a specified maximum power output and, in operation, has headroom determined by the difference between the maximum power output and the present power output of the drive arrangement;

   d. a headroom monitor, coupled to the motorized drive arrangement, for generating a signal characterizing the headroom; and

   e. an alarm, coupled to the headroom monitor, for receiving the signal characterizing the headroom and for warning when the headroom falls below a specified limit.

15. A device in accordance with claim 14, further comprising a handle coupled to the platform, wherein the user input control includes a thumb-wheel disposed upon the handle.

16. A device for carrying a payload including a user, the device comprising:

a. a platform which supports the user in a standing position,

b. a ground-contacting module, mounted to the platform, including at least one ground-contacting member and defining a fore-aft plane;

c. a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system in an operating position that is unstable with respect to tipping in at least a fore-aft plane when the motorized drive arrangement is not powered;

d. a user-operated mode control having first and second modes;

e. a user input control that receives an indication from the user of one of (i) a specified pitch of the device under conditions of motion at uniform velocity and (ii) steering command, depending on the mode of the mode control.

17. A device for carrying a payload including a user, the device comprising:

a. a platform which supports the user in a standing position,

b. a ground-contacting module, mounted to the platform, including a plurality of laterally disposed ground-contacting members and defining a fore-aft plane;

c. a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system in an operating position that is unstable with respect to tipping in at least a fore-aft plane when the motorized drive arrangement is not powered; and

d. a user drive mode selector that on indication from the user causes the motorized drive to operate the ground-contacting members at a uniform

sensor has determined the presence of the user on the device.

22. A method according to claim 21, wherein the proximity sensor is a member, having an operating position and a non-operating position, wherein the member is in the non-operating position in the absence of the user from the device and the member is moveable to the operating position when the user is on the platform.

23. A method according to claim 21, wherein the member includes a plate, disposed on the device, for receiving a foot of the user, and wherein placement of the foot on the plate causes it to move into the operating position.

24. A method according to claim 21, wherein the proximity detector is electronic.

25. A method according to claim 21, wherein the proximity detector includes a semiconductor device.

26. A method according to claim 21, further comprising:

   d. operating a motorized drive arrangement, coupled to the ground-contacting module; the motorized drive arrangement causing, when powered, automatically balanced and stationary operation of the device unless the proximity sensor has determined the presence of the user on the device.

27. A method of using a vehicle to carry a payload including a user, the method comprising:

   a. standing on a platform supporting the user, the platform mounted to a ground-contacting module, which propels the user in desired motion over an underlying surface;

   b. operating a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system wherein the motorized drive arrangement has a present power output and a specified maximum power output and, in operation, has headroom determined by the difference between the maximum power output and the present power output of the drive arrangement;

   c. monitoring the headroom and generating a signal characterizing the

operating position that is unstable with respect to tipping in at least a fore-aft plane when the motorized drive arrangement is not powered; and

c. operating a user-operated mode control to select one of first and second modes;

d. providing via a user input control an indication of one of (i) a specified pitch of the device under conditions of motion at uniform velocity and (ii) steering command, depending on whether the first mode or the second mode has been selected.

33. A method for carrying a payload including a user, the method comprising:

a. providing a device having

i. a platform which supports the user in a standing position,

ii. a ground-contacting module, mounted to the platform, including a plurality of laterally disposed ground-contacting members and defining a fore-aft plane;

iii. a motorized drive arrangement, coupled to the ground-contacting module; the drive arrangement, ground-contacting module and payload constituting a system; the motorized drive arrangement causing, when powered, automatically balanced operation of the system in an operating position that is unstable with respect to tipping in at least a fore-aft plane when the motorized drive arrangement is not powered; and

b. causing the motorized drive to operate the ground-contacting members at a user-controllable speed so as to permit a dismounted user to guide the vehicle running under its own power.

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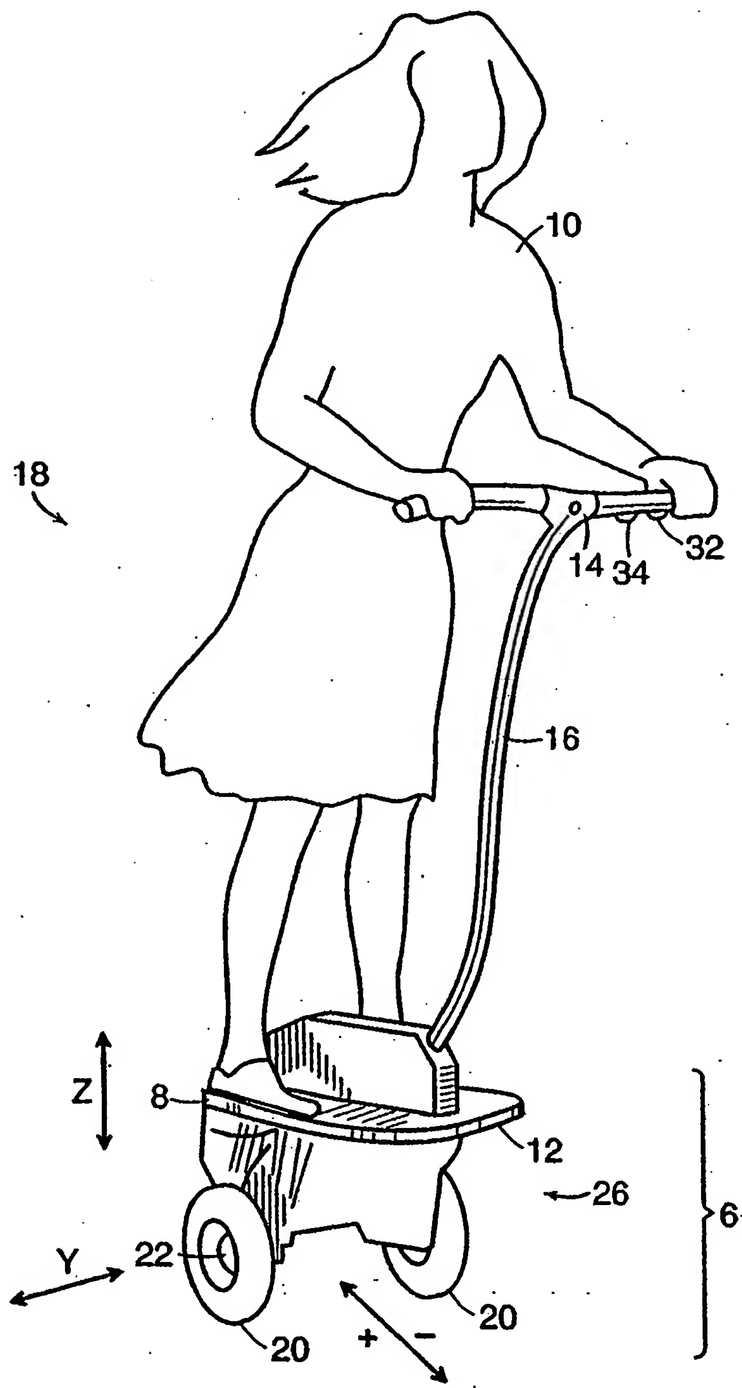


FIG. 1

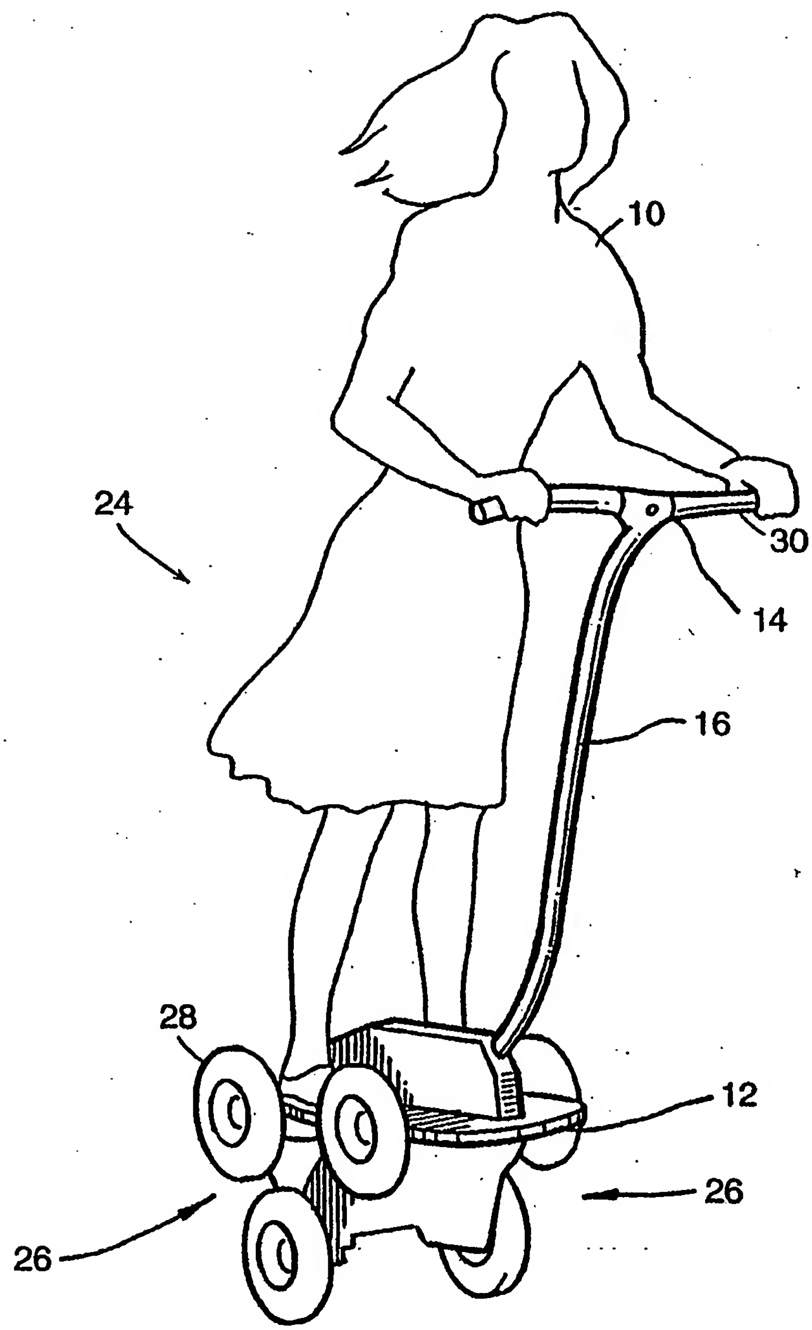


FIG. 2

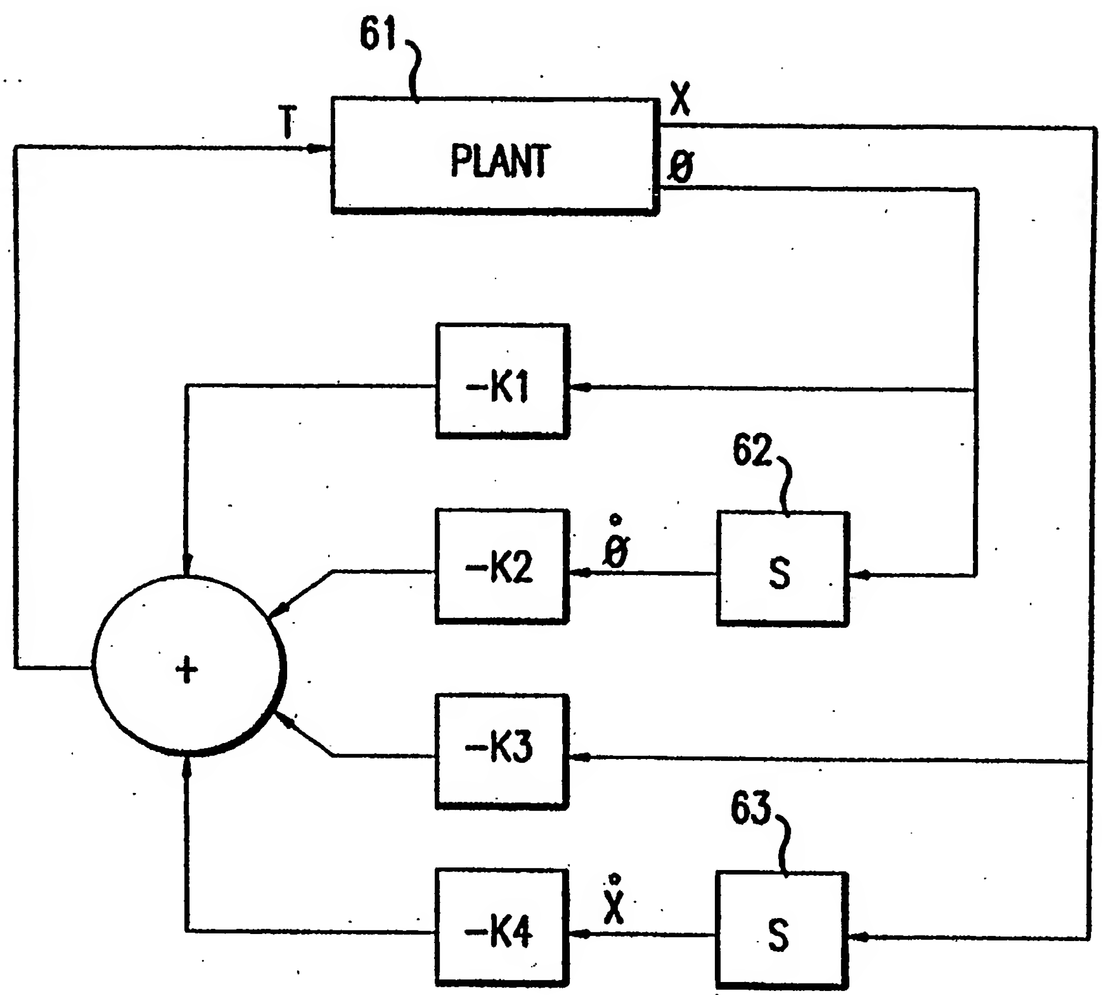
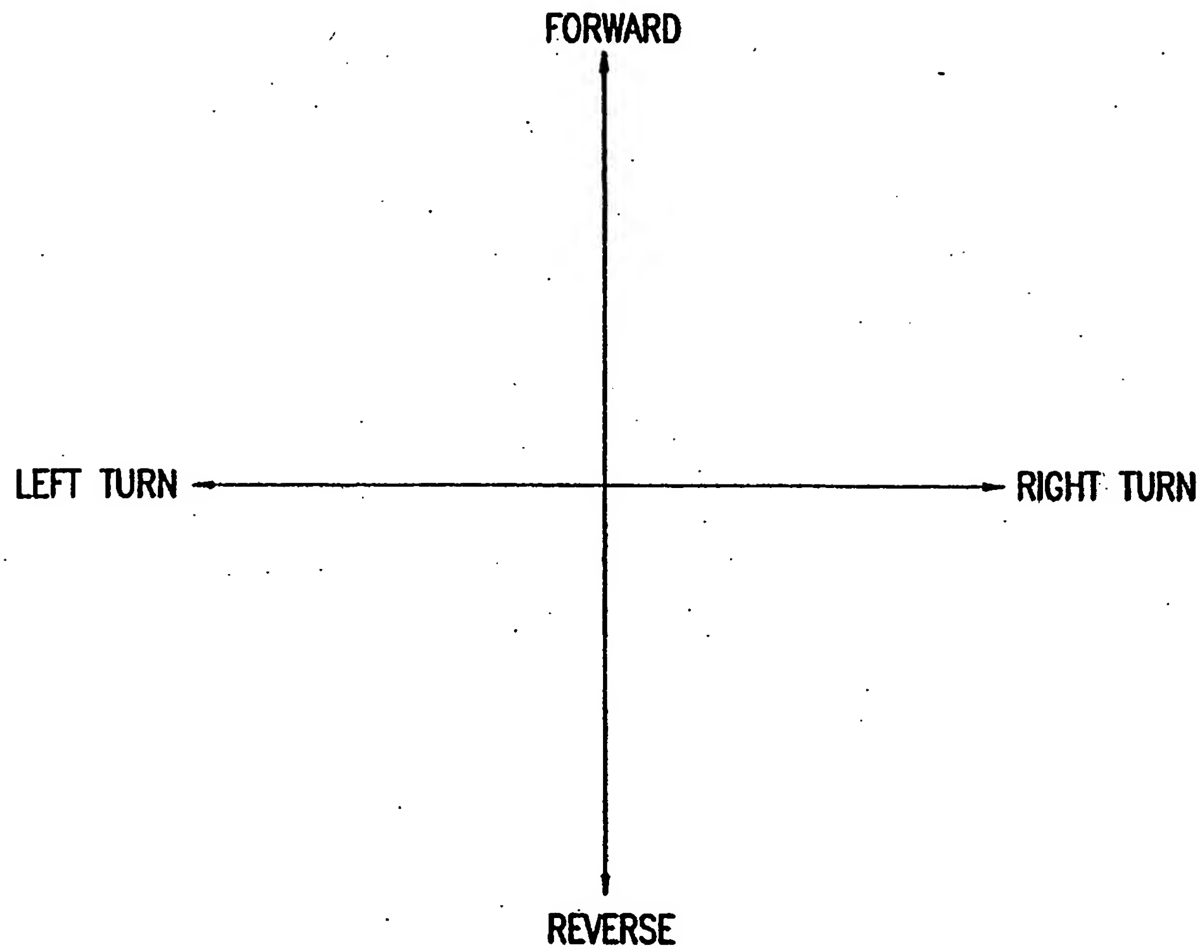


FIG. 3



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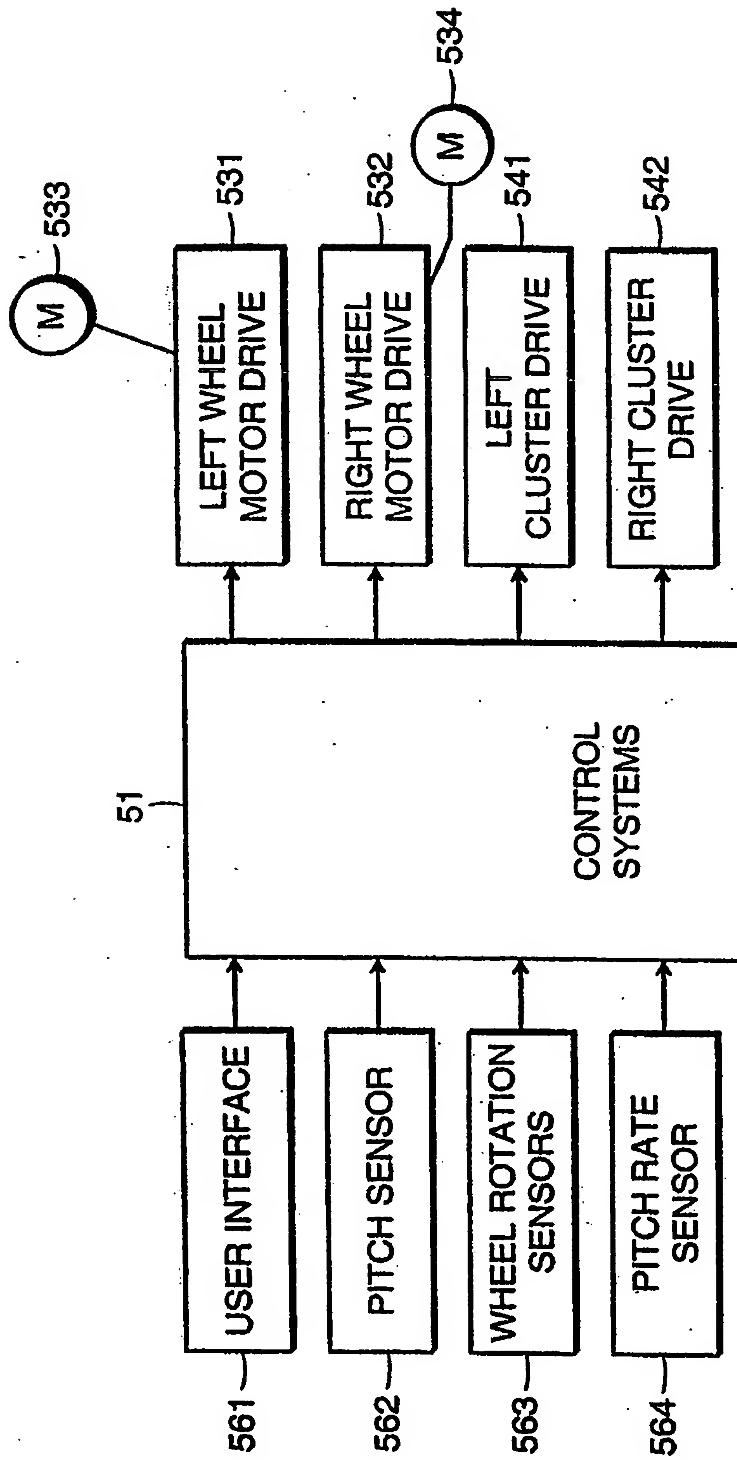
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RIGHT WHEEL MOTOR DRIVE
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RIGHT CLUSTER DRIVE
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USER INTERFACE
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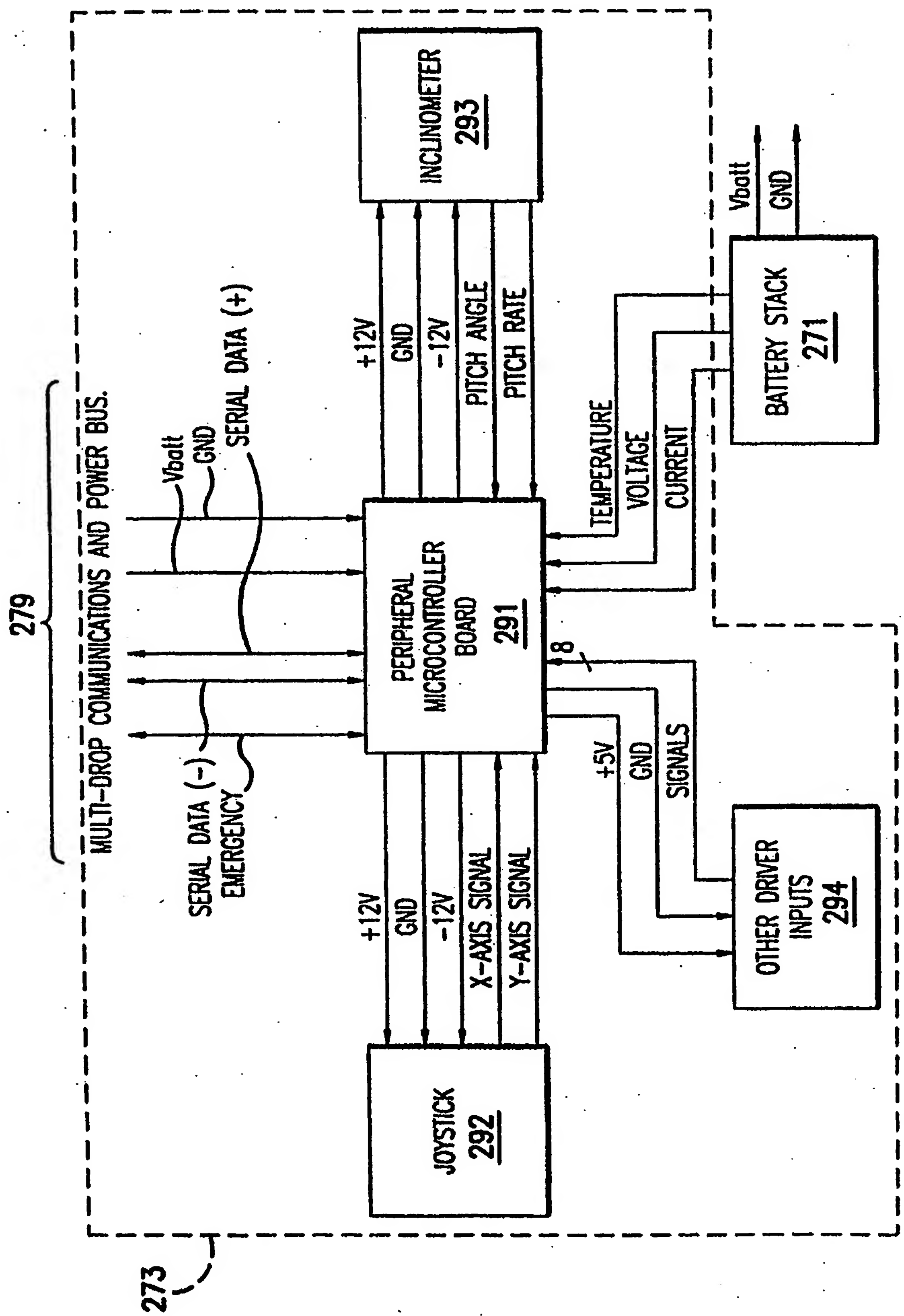
PITCH SENSOR
562
WHEEL ROTATION SENSORS
563
PITCH RATE SENSOR
564

FIG. 5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VOLTAGE
CURRENT
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Vbatt
GND
SERIAL DATA (+)
SERIAL DATA (-)
EMERGENCY
PERIPHERAL
MICROCONTROLLER
BOARD
291
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+5V
GND
SIGNALS
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JOYSTICK
292
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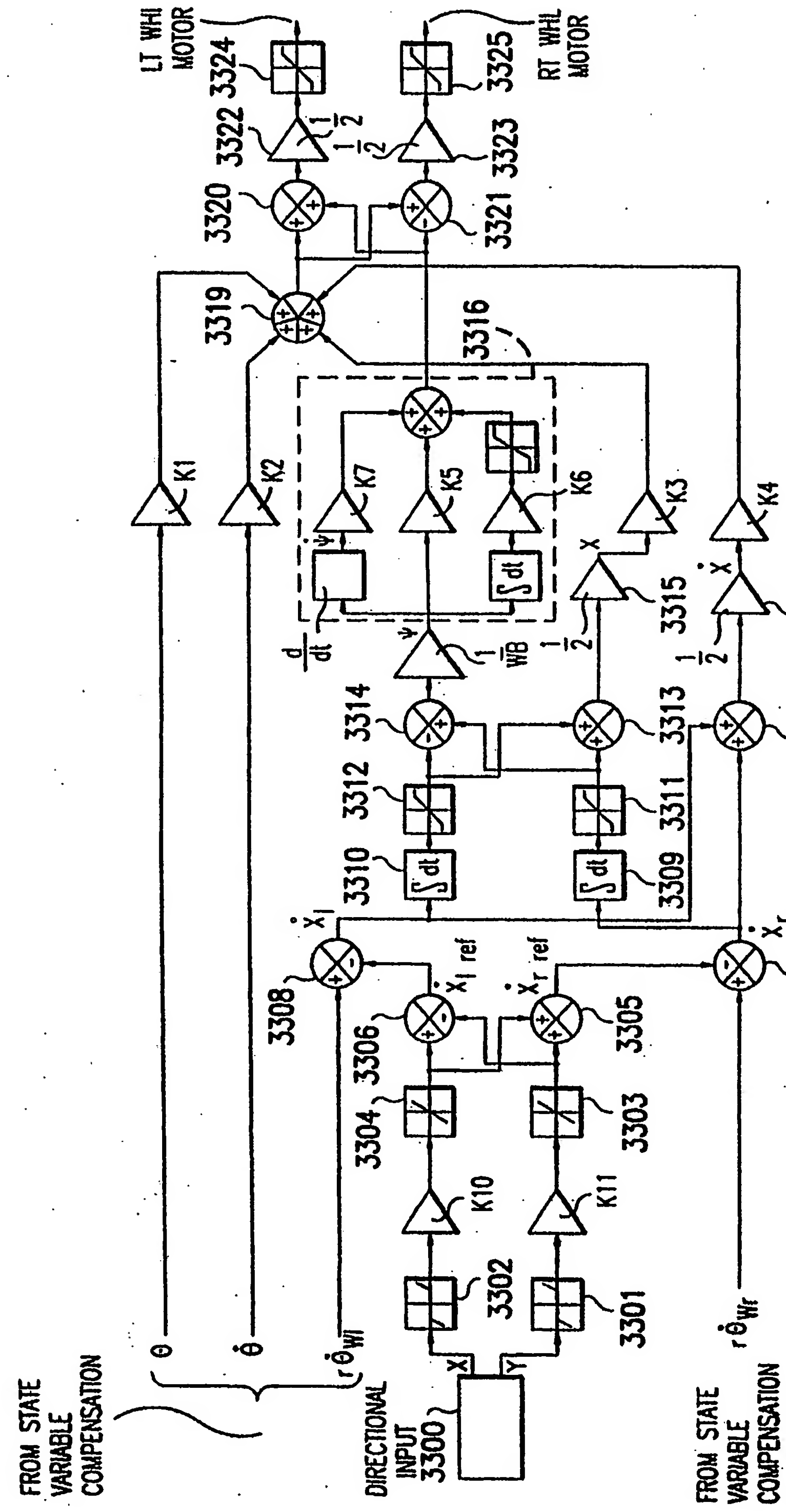
FIG. 6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3309
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3306
3305
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DIRECTIONAL INPUT 3300
FROM STATE VARIABLE COMPENSATION

FIG. 7

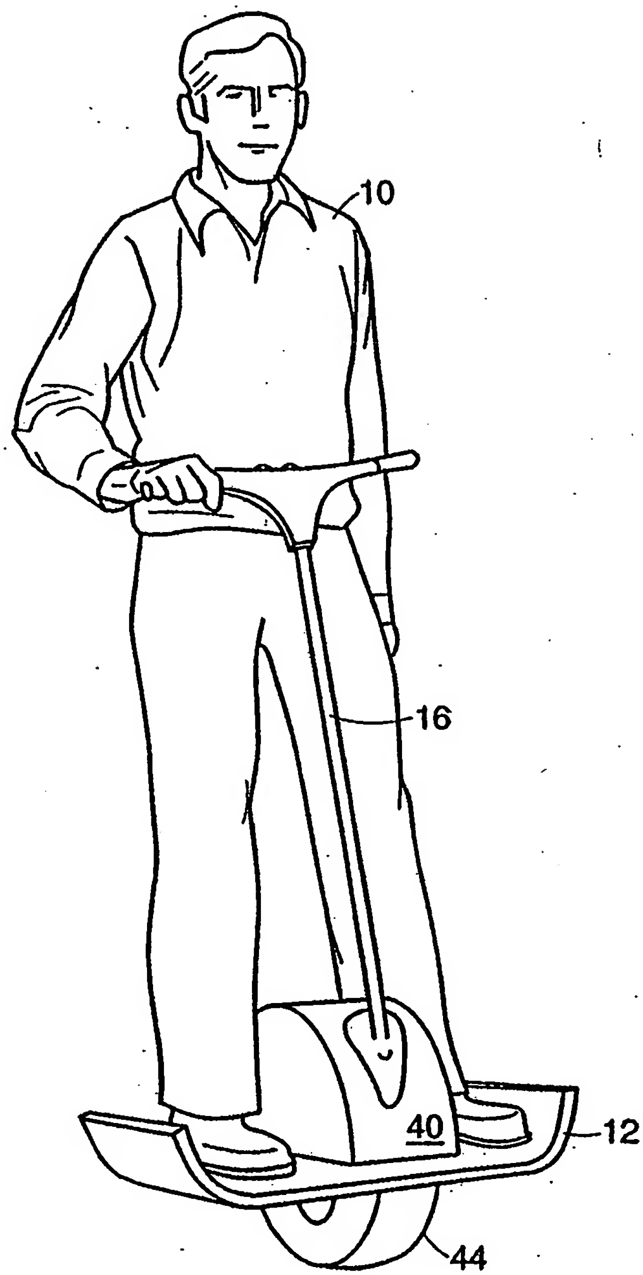


FIG. 8

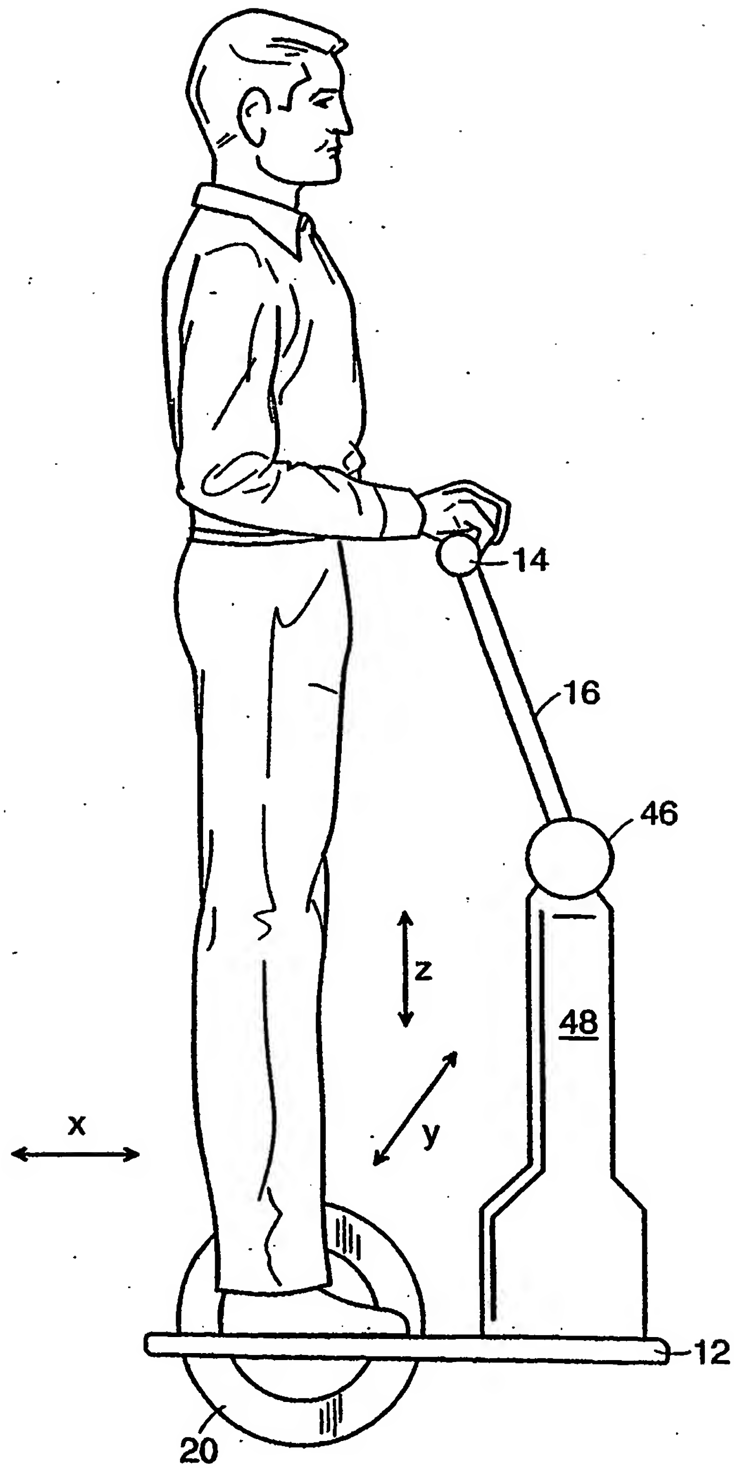


FIG. 9

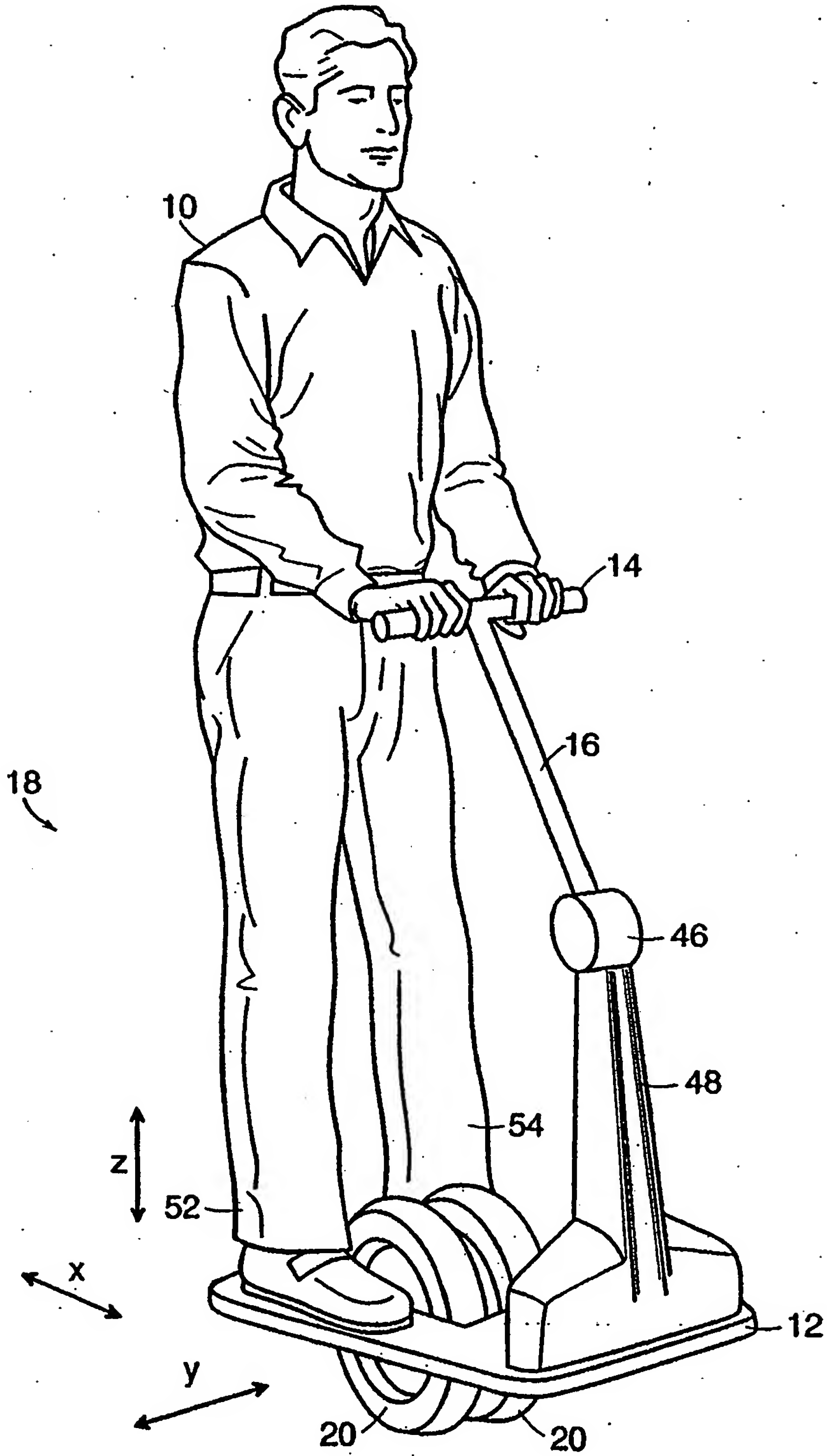


FIG. 10

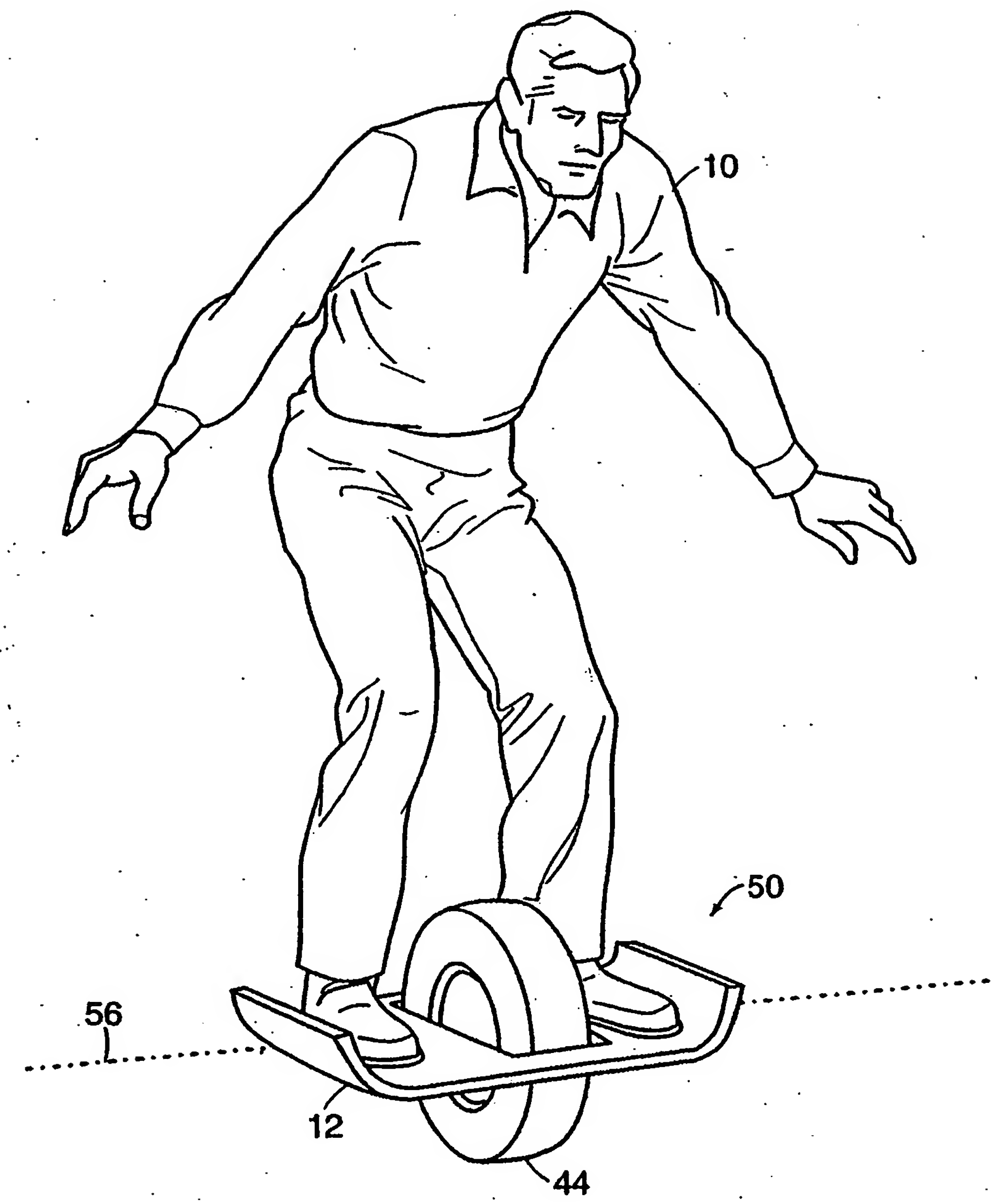


FIG. 11

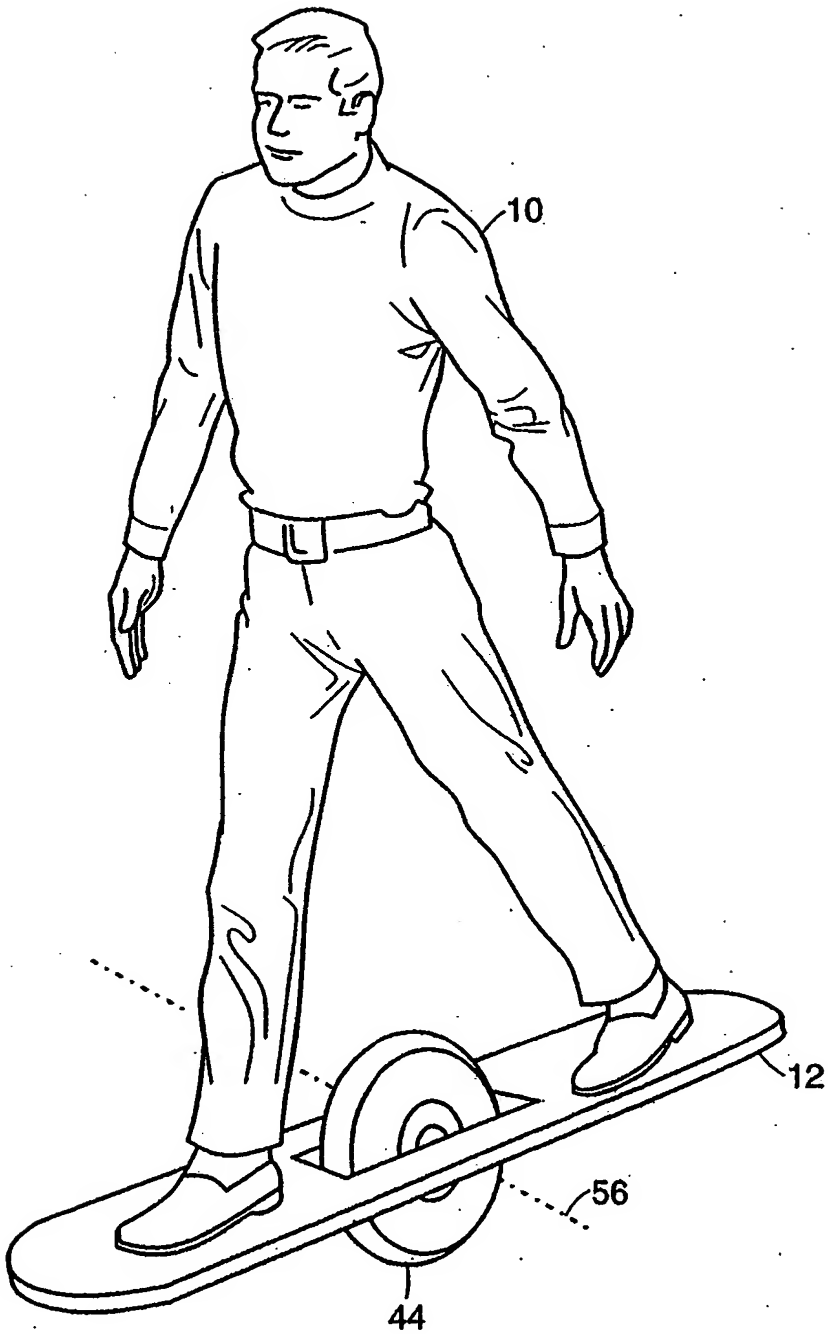


FIG. 12

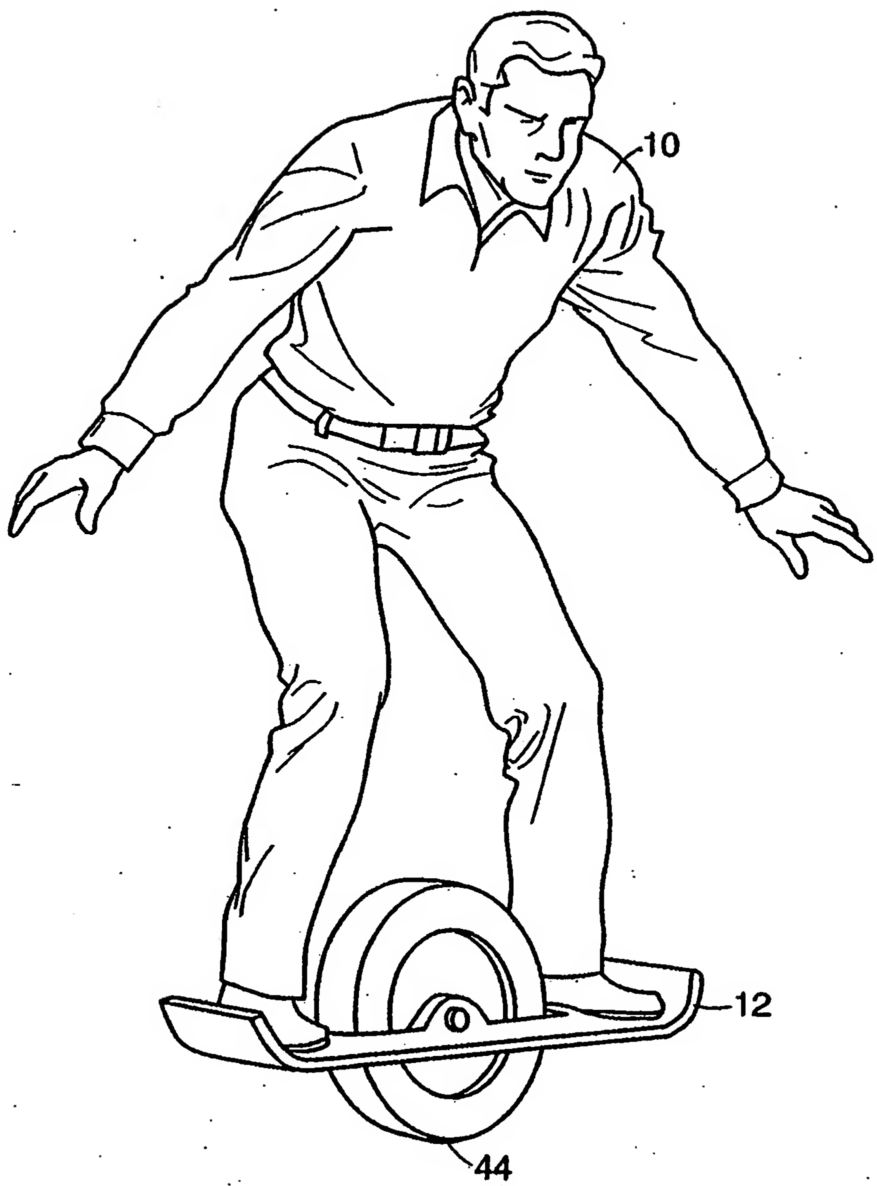


FIG. 13

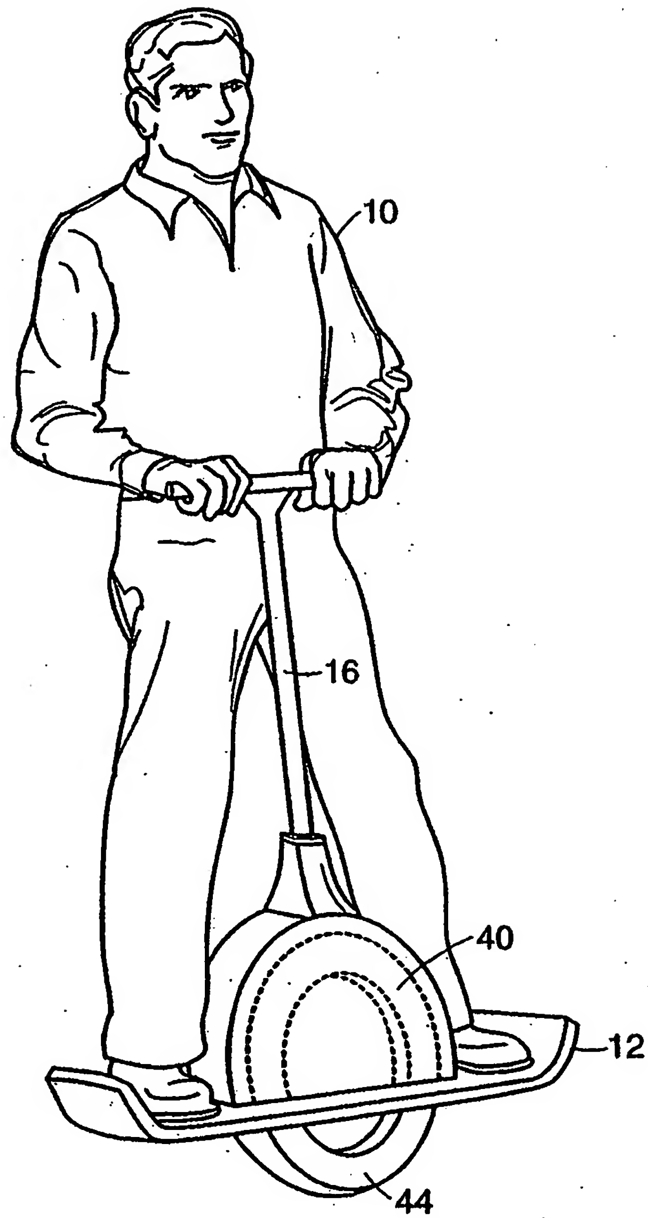


FIG. 14

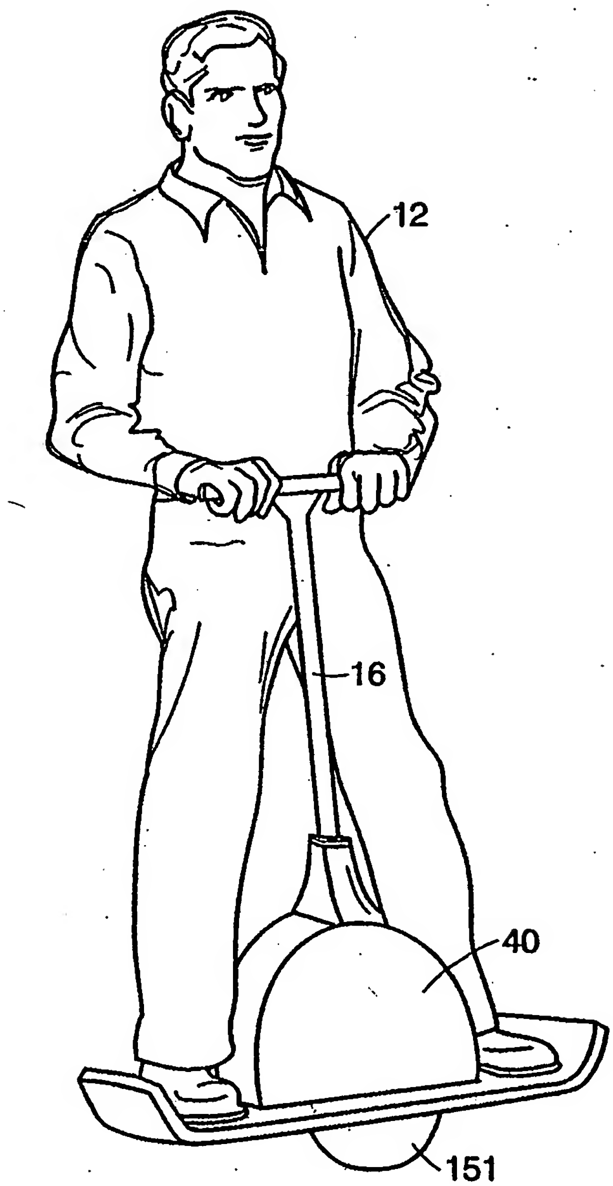
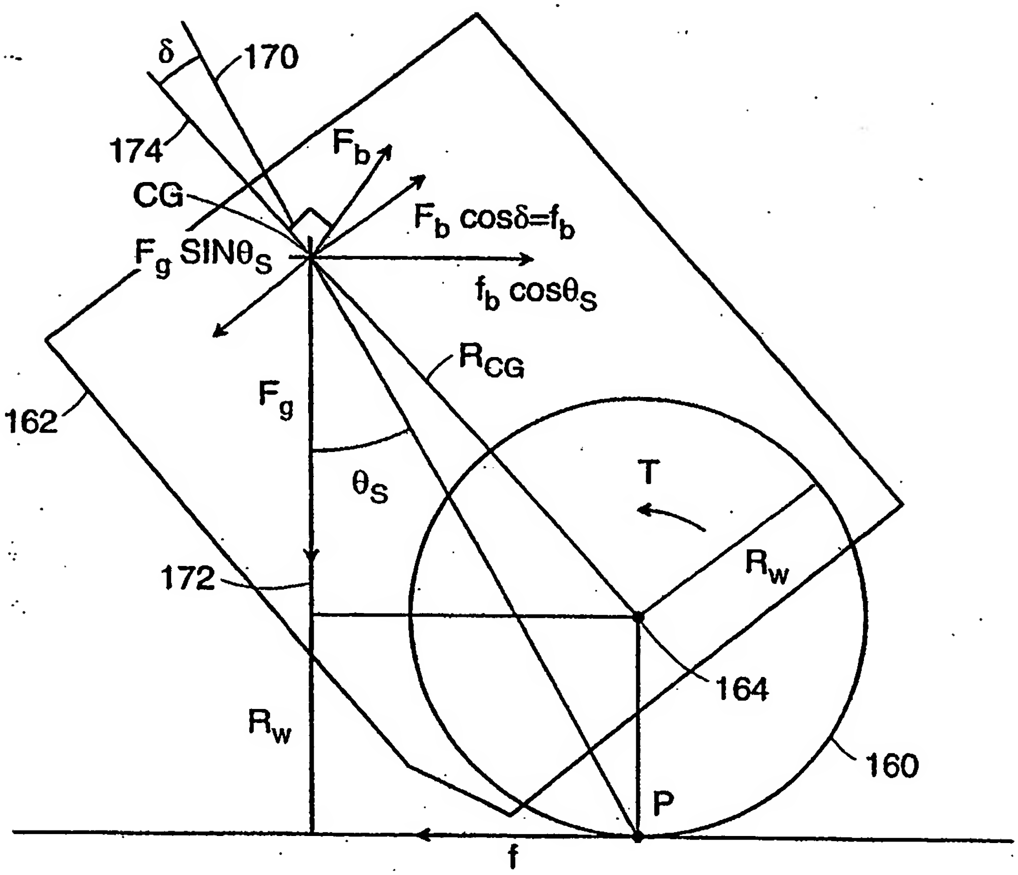


FIG. 15



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R_w
172
164
R_w
160
P
f

FIG. 16

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/15144

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B62K1/00 A61G5/04 A63C17/00 B62D51/02 B62D51/00
B62D37/00 B62K3/00 B62D61/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B62D B62K A61G A63C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 122 (P-1017), 7 March 1990 (1990-03-07) & JP 01 316810 A (TOKUGEI KK), 21 December 1989 (1989-12-21) abstract	1,3,14, 16,18, 20,30,32
Y		2,4,19, 21
A		10,11, 17,27,33
Y	US 3 306 626 A (TADAO KAWADA) 28 February 1967 (1967-02-28) column 2, line 18 - line 40; figures	2,19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 September 2000	26/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hageman, L

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INTERNATIONAL SEARCH REPORT

Inform[illegible]n on patent family members

International Application No
PC[illegible]US 00/15144

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